TROUBLES IN CONSTRUCTING A 48-INCH SUBMERGED MAIN[1]

By F. W. Cappelen

The Minneapolis distribution system required the crossing of the Mississippi River just below the Falls of St. Anthony, with a 48-inch riveted steel pipe ½ inch thick. The river at this point passes through a gorge some 900 feet between bluffs, which, on the east side of the river, reach a height of about 100 feet above low water, and on the west side, 72 feet. On the east side there are 39 feet of sand and gravel to the Trenton lime rock; on the west side, about 11 feet from the top of the ground to the lime rock, which is of the same elevation on both sides of the river. This rock is 25 feet thick and separated from the underlaying St. Peter sandstone by 3 feet of shale. The St. Peter sand rock is some 800 feet thick. The river has cut through the rock, and the river bottom is filled with broken débris of lime rock and boulders; at the deepest point about 40 feet, then the sand rock.

Eight-foot shafts were sunk on both sides of the river, and 8 by 7-foot tunnels extended from the shaft to the edges of the bluffs, 340 feet long on the east side and 60 feet long on the west side, and trenches were dug on the shores as far as possible. This work was started January 3, 1916, and completed May 27, 1916. As the current is very swift at all stages of water, it was necessary to do the river work proper in extreme low water, which occurs from the end of December to the middle of March, mostly in weather below zero. The problem was, how to excavate the trench in the material mentioned? Pile driving was impossible; the water being too swift and shallow for a dredge and no dredge is to be had on the river at this place.

It was decided to build cribs 4 feet wide and 8 feet long, made of 10 by 12-inch timbers, with partly planked bottoms, each to be loaded with about 2 tons of rock. These cribs were to be placed about 14 feet apart on centers across the river, and 16 feet on centers

[1] Read before the Richmond Convention, May 9, 1917.

up and down the stream. On these cribs across the river, 24-inch I-beams 28 feet long would be placed flatways to form a running track for the excavator, which consisted of a stiff leg derrick, with which it was expected to handle a one-half yard orange peel bucket. Before building the cribs some excavation was done with this rig on the low shore on the west side, and it seemed as if the material could be handled that way. Accordingly the placing of the cribs across the river was finished, which did not take long, and the runway completed from shore to shore. The under frame of the derrick was fitted with grooved wheels which travelled on 40–pound rails laid loose on the I beams.

The derrick was then sent back to the west end, and excavating operations continued with the orange peel bucket, but as soon as the river was reached it was found that the bucket would not work satisfactorily at all, and the rig for excavating was changed by attaching to the boom of the derrick a dipper stick, placed about 20 feet from the end of the boom, with a $\frac{3}{4}$-yard steam shovel dipper. The excavation with this machine commenced February 18, 1916, and the ditch was finished March 17, 1916. It was a very hard job. The material was exceedingly bad to handle; big pieces of ledge from earlier erosions were often encountered and they had to be dragged out. Some 2500 yards of this stuff was excavated and dumped on the downstream side. All small material was immediately washed away by the current, leaving the heavier stuff in place. As the excavation progressed towards the east side the cribs were removed. I-beams were placed on the spoil bank as a track to carry the cribs, timbers and I-beams back to the west shore. These beams also formed the pathway between the excavator and the west side.

On March 21, 1916, riveting the 48-inch pipe was commenced. The sections were all 30 feet long, and on March 26, 1916, pulling the pipe towards the east shore was commenced. The first section pulled was 120 feet long. To the end was riveted a torpedo-shaped head 6 feet 7 inches long, with heavy lugs, to which a $\frac{7}{8}$-inch plow-steel iron-center pulling cable was attached. There were also two lugs on the inside of the torpedo to which a $\frac{7}{8}$-inch plow-steel cable was attached. The pulling was done with a 25 horse-power hoisting engine and two triple sets of blocks. After this first section was pulled, 30-foot sections were added and pulled, and on March 30, 486 feet of pipe had been pulled and another day would have

landed the end on the east shore. This very day the ice broke in the upper river, about two weeks ahead of ordinary conditions; and a big ice gorge, which had formed about 15 miles above the falls, broke and a tremendous flood of water came down, in fact, about 54,000 cubic feet per second, which is very nearly the maximum flood recorded on the upper Mississippi, since 1860, when, 60,000 to 65,000 cubic feet came down. We have a low water record in December, 1910, for 1 day, with 668 cubic feet per second. The flood simply picked up the pipe and laid it downstream on the flat west shore, only shearing part of the rivets in one joint about midways. The inside cable, which was always anchored on the west shore, saved the pipe. A few days afterwards, ten million feet of logs broke away at Anoka, 18 miles from Minneapolis, and came down over the falls and cleaned out the spoil bank, I-beams and all. The beams were picked up later.

Nothing could be done now until the river went down again. In July, the pipe was taken from where the flood had left it. It was straightened, joints repaired and tested, and placed in position for handling again under low-water conditions. Meanwhile, the work of building shafts and tunnels went on, and was, as before stated, completed with the lining on May 27, 1916. The shafts were lined with concrete, and the tunnels with 6-inch vitrified tiling.

The ditch was completely filled, of course, after the flood, with sand, gravel, and smaller boulders, and it was decided that the surest and best way to excavate again would be with a drag-line excavating outfit as follows: The track cable was started from a 14 by 14-inch mast, 48 feet high set up on the east shore. The elevation of the cable hitch was about 116 feet, the west end of cable being fastened to a bridle cable subject to pull up or down stream, with a set of $\frac{3}{4}$-inch double blocks at an elevation of about 31 feet. The total span was about 980 feet. The track cable was $1\frac{1}{4}$-inch plow steel, the load line was $\frac{5}{8}$-inch plow steel, and the tension line was $\frac{3}{4}$-inch plow steel. The hoisting engine was rated at 25 horse power with steam pressure of 125 pounds. A $\frac{1}{2}$-yard bucket was used. A 20 horse power engine was placed on the west side. Setting up the cable and engine began September 11, 1916, and drag line excavation on the river proper began October 16, 1916, and was finished January 20, 1917.

The material was about as expected, but in the bottom of the trench large pieces of ledge were encountered that probably had

been shifted into place during the early stages of the flood, and it became necessary to break these large masses by dynamite before the drag could handle them.

The drag line bucket was dumped on staging placed directly over the east side trench, and the material slid down on the spoil bank made on the shore just below the pipe line.

On January 22, 1917, pulling the river sections of the pipe was begun, as before, and the pulling was finished on January 31. The last pull was about 15 feet of a total length of pipe of 698 feet. As the pipe was pulled and sections added, water was let into the pipe on the west end, so as to keep it just about afloat above the bottom of the trench. The pipe was gradually lowered into place from the west end, and closed in and riveted by February 9, 1917. On the east end, a cofferdam had to be built over the pipe, so as to make it possible to cut off the torpedo-head, put in the remaining pipe and make connections with the end of pipe at the mouth of the east tunnel. Much trouble was experienced in unwatering the coffer, as sand rock was encountered inside the dam and no puddle clay could be had with the extreme cold weather, 20° below zero all the time. However, the east end work was closed in on March 10, 1917.

As soon as the pipe had been properly placed, on February 12, the work of anchoring it started. This was done by placing very coarse fabric bags filled with sand and cement mixed 1 : 4, around the pipe, filling the entire trench in spots. Ten such anchors were placed, containing 18,000 sacks. The sand and cement were delivered on top of the west bluff. The sand was heated and mixed dry with the cement in a small mixer and the sacks filled, slid down a plank chute, wheeled to the river edge, then loaded on the drag line bucket which was fitted with a small platform large enough to hold 12 bags. The east side engine pulled the bucket out over the pipe in the river and the west side engine pulled it back. As soon as the sacks had been thrown into place, holes were punched in them by sharp pointed rods to facilitate the wetting of the contents. The cement set satisfactorily. This work was finished March 3, 1917.

On March 21, 1917, the entire work on the east side was finished, with the cofferdam removed. With everything ready, the expected flood came on April 4. The ice gorge broke about 14 miles above the falls and came very violently but without doing

any harm to the main. The river is still high and it is impossible to tell if the ditch is completely filled or not. As soon as the river recedes, it is proposed to empty the pipe and examine it for leaks, before turning on the city supply.

While it may appear that the first excavation was a total loss, the author is convinced that if the tough material had not been removed as was done the first time, it would have been absolutely impossible to do the excavation with a drag line outfit, so the loss in money and time was really comparatively small. The work was done entirely by the city's forces, as is all work in Minneapolis. The pipe was furnished by the East Jersey Pipe Company.

Mr. J. A. Jensen, Assoc.M.Am.Soc.C.E., supervisor, was in direct charge.

Detail cost of river crossing; 48-inch distribution main. Total length of crossing 1526 feet; channel portion 868 feet, tunnel and shaft portion 678 feet

	AMOUNT	COST PER FOOT OF CROSSING
Material:		
1523 feet of 48 by $\frac{1}{2}$, 48 by $\frac{7}{16}$ and 48 by $\frac{3}{8}$ inch riveted steel pipe	$16,591.85	$10.87
48 inch gate and air valves	1,537.69	1.01
Lead, cast iron pipe and specials	287.27	.19
Fittings and incidental supplies	204.55	.13
Bolts, pins, steel and iron	1,001.47	.65
Timber, blocking and lumber	2,041.64	1.33
Cement for bag anchorage and shore wall	800.16	.52
Sand for above, and for filling trench and coffer dam	647.34	.42
Burlap bags for anchorage	1,021.31	.67
Paint and coating material	66.36	.04
Cable	371.00	.24
Electric power for lights and pumping	48.77	.03
Coal for engines and shanty use	1,184.94	.77
Oil, gasoline, candles and waste	742.26	.48
Dynamite and leads	383.14	.25
Tools, rope, derrick repairs, etc	1,001.33	.65
Transporting machinery	194.55	.12
Repairs and parts	387.23	.25
Miscellaneous material	139.83	.09
Total	$28,652.69	18.77

	AMOUNT	COST PER FOOT OF CROSSING
Labor:		
Handling and dumping dredged material	$2,215.79	$1.45
Timbering and sheathing, etc	1,358.84	.89
Hauling pipe and specials	728.79	.48
Hauling supplies and equipment	3,210.90	2.10
Rigging up engines, cable ways, etc	4,062.04	2.66
Foreman and supervision	2,888.45	1.89
Building cribs, etc	1,598.21	1.05
Transporting and setting cribs	315.95	.21
Dredging with shovel	2,416.09	1.58
Dredging with drag line	4,801.61	3.15
Watchmen on engines and camp	1,473.20	.97
Boiler work on steel pipe	4,193.53	2.75
Blacksmith, tool work and repairs	1,203.61	.79
Cutting pipe	287.88	.19
Scraping, cleaning and recleaning and painting pipe	481.31	.32
Setting 48 inch gate and expansion joints	121.50	
Setting air valves	7.50	
Laying and erecting pipe in tunnel and shaft	898.68	.59
Anchoring pipe with filled bags	1,490.86	.98
Unwatering coffer dam	497.70	.33
Concreting east shore	298.05	.20
Pulling pipe into channel	691.43	.45
Moving materials	223.56	.15
Miscellaneous work	688.83	.45
Total	$36,154.31	$23.69
Total cost labor and material*	$64,807.00	$42.46

* Unit costs per foot in channel. Cement for bag anchorage and shore wall, $0.94; sand for same and for filling trench and coffer dam, $0.77; burlap bags for anchorage, $1.19; dynamite and leads, $0.45; rigging up engines, cableways, etc., $4.79; building cribs, etc., $1.88; transporting and setting cribs, $0.37; dredging with shovel, $2.84. dredging with drag line, $5.67; anchoring pipe, $2.20; unwatering coffer dam, $0.59; pulling pipe into channel, $0.82.

The cost of the pipe in the tunnel and shaft was $1.32 per foot.

Detail cost of shafts, 149.7 feet in total vertical length

	AMOUNT	COST PER VERTICAL FOOT
Material:		
Coal for hoist	$150.00	$1.00
Crushed rock for concrete	237.75	1.58
Dynamite and caps	75.00	.50
Tools, etc	125.00	.83
Cement for lining shafts	1,000.00	6.67
Use of hoisting machinery	171.45	1.15
Repairs and parts	50.00	.33
Lumber	200.00	1.34
Drilling 6 inch hole through rock for drainage	66.15	.44
Miscellaneous material	40.00	.27
Total	$2,115.35	$14.13
Labor		
Supervision and foremen	$473.91	$3.16
Watchmen on engines	1,012.20	6.76
Excavating	1,370.89	9.16
Bracing	208.75	1.39
Sheathing	91.00	.61
Bailing water	90.00	.61
Drilling	246.50	1.65
Blasting	34.25	.23
Building trestle	3.00	.02
Cribbing under shaft	5.00	.03
Concreting	286.69	1.92
Rigging up mixer	105.00	.70
Moving derrick	15.00	.10
Placing beams in shaft	76.10	.51
Back filling	102.50	.68
Hauling materials	401.36	2.68
Total	$4,522.15	$30.21
Total cost labor and material	$6,637.50	$44.33

Detail cost of tunnels, 392 feet in total length

Material:		
Crushed rock	$174.24	$.44
Dynamite and caps	75.00	.19
Wall tile for lining	724.66	1.85
Tools, etc	125.00	.32
Cement	160.30	.41

Detail cost of tunnels, 392 feet in total length—Continued

	AMOUNT	COST PER VERTICAL FOOT
Repairs	$50.00	$.13
Lumber	50.00	.13
Drain tile	42.14	.11
Power and lights	75.00	.19
Miscellaneous material	40.00	.10
Total	$1,516.34	$3.87
Labor:		
Supervision and foremen	$473.91	$1.21
Excavating	1,260.28	3.22
Drilling	104.00	.27
Blasting	84.75	.22
Bracing	229.13	.58
Laying tracks	142.20	.36
Excavating for drain tile	72.75	.19
Back filling	375.63	.96
Laying drains	69.25	.18
Excavating for lining wall foundation	90.50	.23
Lining tunnel with tile walls and arch	604.19	1.54
Concreting wall foundation	344.00	.88
Hauling materials	401.36	1.02
Total	$4,251.95	$10.84
Total cost labor and material	$5,768.29	$14.71